Russia has apparently taken the lead in trying t determine the most critical period of growth for field crops, although Canada has recently started investigations along similar lines.

The United States Weather Bureau has long maintained special services in the interest of agriculture which may be classed under agricultural meteorology, such as the special corn and wheat region service, cotton and rice service, fruit service, etc.

The personal investigations of the author have been to find the critical period for farm crops and the weather most affecting them by correlating the crop yields with the weather conditions for periods long enough so that accidental coincidences will be eliminated.

This has been done graphically by the curve chart and the dot chart, as well as by the mathematical calculation for giving the exact measure of relation between two factors, as expressed in the correlation coefficient.

The crops considered in this paper have been corn, potatoes, and winter wheat, and the periods covered between 50 and 60 years.

Most of the correlations have been made between the yields and the temperature and rainfall for calendar months and groups of months. From these correlations it has been found that the most important weather factor for corn is rainfall and the most important month July. For potatoes the most important factor is temperature, and the critical month is also July. March is the critical month for winter wheat and temperature is the most important weather factor.

The critical rainfall point for July, in its effect upon the corn yield, is 3 inches. It is found that a variation in the rainfall of one-fourth inch in July in Ohio at this critical rainfall point makes a variation in the corn yield of nearly $3,000,000, and a variation of one-half inch in the rainfall a variation in the yield of over 15,000,000 bushels. In the four greatest corn States of the central part of the United States a variation of one-half inch of rain at this critical point makes a variation in the value of the amount of corn raised of $5 an acre, or a total of $150,000,000.

When the rainfall in Ohio in July is more than 1 inch above the normal the probability of the corn yield being above the normal is 92 per cent, and when the rainfall is 1 inch or more below the normal, the probability of the corn crop being above the normal is only 13 per cent.

While July must be wet and moderately warm for the best crop of corn, it must be cool and moderately wet for the best development of potatoes. If July averages more than one degree a day warmer than the normal the probability of the potato crop being above the average is only 12 per cent. When the temperature has been above the normal and the rainfall more than one inch either greater or less than the normal, the yield of potatoes has always been less than the normal.

Weather effects for shorter periods than months have been determined, and it has been found that the most important 10 days for corn is immediately following blossoming, when it must be wet and moderately cool. For potatoes the 10 days following blossoming must be cool and should be moderately wet. For arbitrary 10-day periods the most critical for corn is from August 1 to 10, and for potatoes from July 1 to 10.

In connection with winter wheat it is found to be much more difficult to determine the dominant weather factor as well as the critical period of growth for any all-seeded crop or one with a long growing period than for spring-seeded crops or those with a comparatively short-growing period.

Careful correlations between rainfall for months and groups of months and the yield of winter wheat in Ohio show that the rainfall is neither too great nor too little often enough to have an appreciable effect upon the yield in calculating for the correlation coefficient.

Neither are the temperature variations great enough to show a dominating effect except for the month of March. If we consider only those years when the mean temperature has varied two degrees or more a day from the normal the probability of a wheat yield being above the normal is 94 per cent with a warm March and only 25 per cent with a cold March.

It is customary to credit a good snow covering with a good yield of winter wheat or to say that a lack of snow blanket is sure to cause a poor yield. But careful correlations made in Ohio seem to show no beneficial result from a snow covering or damage from lack of it. At least the snow covering does not have a dominating influence. On the other hand, the studies seem to show that bare ground with freezing and thawing weather in January is beneficial.

Further, while a snowfall in January seems to be favorable it is found, contrary to the usual opinion, that snowfall in March is decidedly detrimental to winter wheat. In several counties of the State it has been found that in nearly every instance the greater the snowfall in March the less the wheat yield, and that when the snowfall is light the yield is nearly always above the normal.

It is believed that one of the first developments of agricultural meteorology should be to find the critical period in the growth of the various staple crops in different sections of the country, and that when these are found all farm activities can be put on a much more profitable basis.

Those who irrigate in the western districts will know better just when to apply the water for the best results, and farmers in the central and eastern districts will learn that it will pay to aid natural rainfall by irrigation.

It is believed that this new agricultural meteorology when properly developed will enable us to express rainfall in terms of cash value rather than in inches, temperature in the ability of the farmer to buy instead of in degrees, and sunshine in the increased number of automobiles and tractors rather than in calories.

BREATHING WELLS AND PRESSURE CHANGES.

Mr. John Free, of New Carlisle, Clark County, Ohio, has kept a daily record of the "breathing" of his well (see this REVIEW, Nov., 1915, p. 562) through the month of February, 1916, and has sent it to this bureau with the remark "In looking over the high and low pressure maps for November I see that none crossed Ohio; but my well was active just the same."

This record is very interesting for it permits us to compare the subterranean conditions with the pressure-changes going on at the earth's surface and recorded at our Weather Bureau stations. The following table presents Mr. Free's observations, and in addition the 12-hour changes in pressure at Columbus, Ohio, as telegraphed to the central office at 8 a. m. and 8 p. m. daily.

TABLE 1.—*Record of breathing well at New Carlisle, Ohio, and pressure-changes at Columbus, Ohio, February, 1916.*

Date.	Weat	Well blew—		Remarks.	Columbus, Ohio, 12-hour pressure-changes.	
		A. M.	P. M.		8 a. m.	8 p. m.
Feb. 1	Fair	In	In		0.28	0.16
2		Out	Out	Snow flurry at night	−0.12	None.
3		In	In		0.10	0.06
4		In	Out	In to 9 a. m.; out at 1 p. m.	0.08	−0.18
5		Out		Out till evening	−0.22	−0.04
6	Snowing	Out		Stopped blowing in evening.	−0.22	None.
7		In	Quiet	Quiet at 8 p. m.	0.26	0.26
8			Out		−0.06	−0.34
9		Quiet	In	Quiet at 9 a. m.	0.06	0.24
10		In	Out	In till 9 a. m.; out at 1 p. m.	0.08	−0.02
11	Raining	Out	In	In at 4 p. m.	−0.14	−0.14
12				[No record]	−0.10	0.12
13	Snow flurries	In	In	Snow flurries, p. m.	0.22	0.24
14		In	Out	Out at 4 p. m.	0.10	−0.06
15		Out	Out		−0.08	−0.16
16		Out	Out		−0.18	−0.22
17		Out	Out		−0.06	−0.04
18	Blizzard	Out	In	In at 3 p. m.	−0.16	0.28
19	Snowing	In	Out	Out at 1 p. m.	+0.10	−0.10
20		Out	In	In at 1 p. m.	−0.24	0.24
21		In	Out	Out in evening	0.34	−0.10
22		Out	Out		−0.16	−0.20
23		Out	In	Out until 9 a. m.; in in evening.	−0.06	0.10
24		Out	Out		−0.14	−0.06
25		Quiet	Quiet		−0.06	0.10
26	Snowing	Out	In	Out until 2 p. m.	−0.16	0.06
27		In	In		0.22	0.14
28		In	Out	In until 2 p. m.	0.06	−0.14
29		Out	In	Out until 9 a. m.	−0.04	0.16

Columbus, Ohio, is about 55 miles (87 kilometers) almost due east of New Carlisle, and its pressure changes may be taken as sufficiently representative of those taking place at New Carlisle to serve for comparison with the well breathings. It appears from Table 1 that, out of 56 recorded pressure-changes and well "breathings," *rising pressure-changes* were accompanied by inspirations 22 times and no breathing in 4 cases, while *falling pressure-changes* were accompanied by expiration 27 times and by no breathing only twice. On one occasion (afternoon of the 11th) there seems to have been a case of inspiration during apparent falling pressure, which may represent an occasion of temporary rise in pressure between the two telegraphic reports given in the table.

The table will make it plain that even though the daily weather maps show no *centers* of high or of low pressure passing directly over Ohio, and certainly not over New Carlisle, nevertheless the atmosphere over the State was constantly varying in pressure as storms traveled across the country. Thus, from the morning of the 1st to the evening of the 4th of February, 1916, Mr. Free's well was taking in air, predominantly, while the synchronous pressure changes were predominantly positive. This was under the influence of the general rise in pressure due to the eastward movement of the high area whose crest occupied the Dakotas, Nebraska, and Kansas on the morning of February 1, but had moved across Ohio to West Virginia by the morning of February 4.

Again on February 13–14 the well was breathing in under the influence of a slightly rising pressure which changed to falling pressure on the afternoon of the 14th, and the well exhaled continuously for four days as the pressure steadily fell before the advance of the southern periphery of a great low whose center never came south of the Great Lakes. During this period Ohio was always on the southern skirts of the depression; the center of the low did not pass over Ohio.

Applications of this phenomenon.—This relation between pressure-changes and earth breathing has been recognized and studied for some time. Private efforts have been made in England, and to some extent in this country, to utilize the pressure-changes in forecasting conditions favorable to explosions of gases in mines. England has not made public efforts to forecast such conditions for the benefit of the mine operators, but Dr. W. N. Shaw, Director of the Meteorological Office, has outlined a scheme looking toward the preparation of such forecasts.[1] In the United States the Weather Bureau does not issue official forecasts or warnings of conditions producing mine explosions; but it authorizes certain of its local forecasters to telegraph marked changes in pressure to the mine operators and thus enables the latter to form their own conclusions as to the probability of danger.—C. A., jr.

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ALTO-CUMULUS WITH VIRGULUS.

The cloud form illustrated by a rough sketch in REVIEW for December, 1915, page 614, but more properly called "alto-cumulus with virgulus" (as was pointed out by Prof. Talman in the issue for January, 1916, p. 2) seems to be better known in the United States than the first correspondent thought.

Mr. J. B. Willsea, of Fruita, Colo., writes under date March 25, 1915,—

> This class of clouds is seen frequently in this valley [Grand River] especially in the spring when we are watching for frosts that do our fruit blossoms.
>
> Possibly some may be interested in the shape of these clouds as we see them here. I will try to make sketches of them this spring.

Mr. Willsea calls our attention to the fact that these clouds were described and sketched but not specifically named at Blue Hill, Mass., as long ago as 1888. The following is taken from H. H. Clayton's "Discussion of cloud observations:"[2]

> The formation of cirrus from clouds of the cirro-cumulus or alto-cumulus type has been repeatedly observed. Figures *m*, *n*, [op. cit., Plate VI], are all taken from rough sketches made by the writer at the time of observation. These forms apparently all result from descending cloud particles. The heavy particles fell first and succeeding particles followed the same path on account of the less resistence, and thus formed long fibers which were usually carried backward from the cloud on account of the decrease of wind velocity with lower altitude. The form *m*, with fibers suspended nearly vertical, was observed on several occasions, and care was taken to ascertain that the apparently nearly vertical direction of the fibers was not an effect of perspective. As a rule, the suspended fibers were drawn backward in the direction from which the cloud moved, as shown in *n*. On watching these clouds it is seen that the fibers move continually outward from the clouds, until the entire cloud is drawn out into cirrus. Several times cirrus (!) were observed to elongate from the top of cirro-cumulus clouds, as shown in figure *k*, Plate VI, the sketch made July 3, 1888, the cirrus being apparently drawn out by a more rapid current at the top than at the base of the cirro-cumulus. Similar formations of cirrus from the tops of the cirro-cumulus clouds were observed on several occasions.
>
> The writer has also repeatedly seen cirrus-like fibers drawn out from small cumulus clouds, sometimes from the top and sometimes from the base of the cloud, and once from both at the same time, thus giving the cloud a very fibrous appearance. Most of these cases occurred during the latter part of winter or in the spring, and usually accompanied the setting in of a very low temperature, sometimes below zero Fahrenheit. These clouds appear to float at the same altitude as ordinary cumulus. The following note of measurements made on the velocities and altitudes of this type of cloud was recorded on March 3, 1894: "At 3 p. m., one or two large cumulus in the south had

[1] See his "Forecasting weather". London, etc., 1911, pp. 306–312.

[2] Observations made at the Blue Hill Meteorological Observatory. Discussion of the cloud observations, by H. Helm Clayton. Cambridge, Mass., 1896, pp. (Annals, Astronomical Observatory, Harvard College, 30, pt. 4.)